# Design and Implementation of an Automatic Railway Gate Control System Using Ultrasonic Sensors and Arduino

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***Abstract*—This project presents the design and implementation of an Automatic Railway Gate Control System aimed at enhancing safety at railway crossings by eliminating the need for manual gate operation. Railway crossings are critical points where accidents frequently occur due to delayed human response or negligence. The proposed system utilizes ultrasonic sensors to detect the arrival and departure of trains. When a train approaches the crossing, the sensor transmits a signal to the Arduino microcontroller, which processes the data and activates a servo motor to automatically close the railway gate. Once the train passes and a second sensor confirms its departure, the microcontroller commands the servo motor to reopen the gate. This system significantly reduces human intervention, improves response time, and minimizes the risk of accidents at unmanned railway crossings. The system is low-cost, reliable, and demonstrates how automation and sensor technologies can be effectively applied to enhance railway safety and traffic management.**

***Index Terms*—Arduino Uno, Ultrasonic Sensor, Servo Motor, Railway Gate Control, Embedded System, Automation.**

## I. INTRODUCTION

Railway transportation is one of the most widely used and cost-effective modes of transportation across the world. It plays a vital role in the economic development of countries by facilitating the movement of passengers and goods over long distances. However, railway crossings are considered critical points in railway infrastructure where railway tracks intersect with roads used by pedestrians and vehicles. These crossings often pose significant safety risks, particularly when gates are operated manually or when there is no proper monitoring system [1].

In many regions, railway gates are still controlled manually by gatekeepers who are responsible for opening and closing the gates when a train approaches or leaves the crossing. Human involvement in such operations may lead to errors, delays, or negligence, which can cause severe accidents and loss of life. In several cases, unmanned railway crossings exist where there is no gate operator available to manage the traffic. These unmanned crossings significantly increase the risk of accidents between trains and road vehicles [2].

To address these challenges, automation technologies are being increasingly adopted in transportation systems. Automated railway gate control systems are designed to detect approaching trains and automatically control the opening and closing of railway gates without requiring human intervention. Such systems improve reliability, reduce human errors, and ensure the safety of both railway passengers and road users [3].

The Automatic Railway Gate Control System proposed in this project utilizes ultrasonic sensors to detect the presence of trains approaching and leaving the railway crossing. The sensors transmit signals to a microcontroller that processes the information and controls the operation of servo motors connected to the railway gates. When the system detects an approaching train, it automatically closes the gate to stop road traffic. Once the train has passed and the second sensor confirms its departure, the gate reopens automatically.

Embedded systems and sensor technologies make it possible to design intelligent safety mechanisms that can operate efficiently in real-time environments. The proposed system demonstrates how microcontrollers, sensors, and actuators can work together to create an automated solution that improves railway safety and reduces the possibility of accidents at railway crossings [4].

This project focuses on developing a low-cost and reliable automatic railway gate control system suitable for implementation in unmanned railway crossings. By integrating sensors and microcontroller-based control mechanisms, the system ensures timely detection of trains and automatic gate operation, thereby enhancing safety and efficiency in railway transportation systems.

## II. OBJECTIVES

1. The main objectives of the Automatic Railway Gate Control System project are:
2. To design an automated system that controls railway gates without human intervention [5].
3. To detect approaching trains using ultrasonic sensors.
4. To develop a microcontroller-based control system for processing sensor data.
5. To automatically close the railway gate when a train approaches the crossing.
6. To automatically open the gate after the train passes the crossing.
7. To reduce accidents caused by human error in manual gate operation.
8. To demonstrate the use of embedded systems in railway safety applications.
9. To develop a cost-effective and reliable railway automation solution.
10. To improve the safety of road users and railway passengers.
11. To provide a prototype model that can be further developed for real-world implementation [6].

Block Diagram

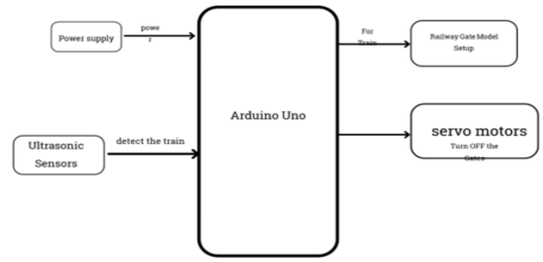


Fig.1. Block diagram of proposed Automatic Railway Gate Control System

Working Process

The Automatic Railway Gate Control System continuously monitors the railway track using ultrasonic sensors placed near the crossing. These sensors detect the presence of an approaching train by measuring the distance between the sensor and the object. When the train enters the detection range of the first sensor, the sensor sends a signal to the Arduino microcontroller [7].

Upon receiving the signal, the microcontroller processes the input and sends a command to the servo motor to close the railway gate. This action prevents vehicles and pedestrians from crossing the railway track while the train is approaching or passing through the crossing.

Once the train passes the crossing area, it is detected by the second ultrasonic sensor placed on the opposite side of the track. This sensor sends another signal to the microcontroller indicating that the train has cleared the crossing. The microcontroller then activates the servo motor to open the railway gate, allowing road traffic to resume [8].

The system operates automatically without requiring human intervention. The microcontroller continuously checks the status of the sensors and ensures that the gate opens and closes at the appropriate time.

Step-by-Step Working Process:

1. The system remains in monitoring mode when no train is present.

2. The first ultrasonic sensor detects the approaching train.
3. The sensor sends a signal to the Arduino microcontroller.
4. The microcontroller processes the signal and activates the servo motor.
5. The servo motor rotates to close the railway gate.
6. The train passes the railway crossing safely.
7. The second ultrasonic sensor detects the departure of the train.
8. The sensor sends a signal to the microcontroller.
9. The microcontroller commands the servo motor to reopen the gate.
10. Road traffic resumes normally after the gate opens [9].

Existing System

In many railway networks, especially in developing countries, railway crossing gates are still operated using manual or semi-automatic systems. These systems depend on human gatekeepers who are responsible for controlling the opening and closing of railway gates when a train approaches or leaves the crossing. The gatekeeper receives information about an approaching train from the nearby railway station through telephone communication, signaling systems, or manual instructions [10].

Once the gatekeeper receives the signal that a train is approaching, the gate is manually closed to stop vehicles and pedestrians from crossing the railway track. After the train passes the crossing, the gatekeeper reopens the gate to allow road traffic to continue. Although this method has been used for many years, it heavily relies on human accuracy and coordination.

In some areas, particularly rural regions, there are unmanned railway crossings where no gatekeeper is present. In such locations, warning signs or signal lights may be installed to alert road users about approaching trains. However, these systems do not physically block vehicles from entering the railway track area, which increases the possibility of accidents [11].

Another type of existing system involves mechanical or electromechanical gate control systems that operate using track circuits or signal relays. These systems are more advanced than purely manual systems but still require human supervision and maintenance.

Despite the presence of these systems, railway crossing accidents remain a significant concern in many countries. Many accidents occur because of delayed gate closure, lack of proper communication, human negligence, or poor monitoring of railway crossings.

Drawbacks

1. Human Errors: Manual gate control systems depend on human operators. Mistakes such as delayed gate closure, incorrect signaling, or negligence can lead to serious accidents [12].
2. Delayed Response: In manual systems, the gatekeeper must receive information about the train and then manually close the gate. This process may cause delays, especially if communication between railway stations is slow.
3. Unmanned Railway Crossings: Many railway crossings are unmanned, meaning there is no gatekeeper present to control traffic. Vehicles and pedestrians may attempt to cross the tracks without knowing that a train is approaching [13].
4. Lack of Real-Time Monitoring: Traditional systems often lack real-time monitoring capabilities. Railway authorities may not be able to track the status of railway gates or identify operational failures quickly.
5. High Risk of Accidents: Because of human errors and poor monitoring, manual systems increase the chances of collisions between trains and road vehicles.
6. Increased Operational Costs: Manual gate systems require manpower for operation and maintenance. This increases operational costs for railway authorities [14].
7. Inefficient Traffic Management: Manual systems may keep gates closed longer than necessary, causing unnecessary delays for road traffic.
8. Limited Safety Mechanisms: Most traditional systems lack advanced safety mechanisms such as automatic detection, warning alarms, and obstacle detection systems.

## III. PROPOSED SYSTEM

The proposed system is an Automatic Railway Gate Control System designed to improve safety and efficiency at railway crossings by eliminating manual gate operation. The system uses ultrasonic sensors, a microcontroller, and servo motors to automatically control the opening and closing of railway gates [15].

In this system, ultrasonic sensors are placed near the railway track to detect the arrival and departure of trains. When a train approaches the railway crossing, the sensor detects the train and sends a signal to the microcontroller. The microcontroller processes the sensor data and activates a servo motor that automatically closes the railway gate.

Once the train passes the crossing and is detected by another sensor placed on the opposite side, the microcontroller sends a command to reopen the gate. This automatic operation ensures that the gate closes and opens at the correct time without requiring human intervention [16].

The proposed system uses an Arduino microcontroller as the central control unit. The microcontroller continuously monitors sensor inputs and controls the gate mechanism accordingly. The system also includes a power supply unit and connecting components required for operation.

Proposed System Advantages

1. Reduced Human Intervention: The system operates automatically using sensors and a microcontroller, eliminating the need for manual gate operation [17].
2. Improved Safety: Automatic detection of trains ensures that gates are closed at the correct time, reducing the risk of accidents at railway crossings.
3. Fast Response Time: The system responds quickly to the detection of trains, allowing gates to close and open without delays.
4. Suitable for Unmanned Crossings: The proposed system is particularly useful for unmanned railway crossings where there is no gatekeeper available [18].
5. Cost-Effective Solution: The system uses low-cost components such as Arduino microcontrollers, ultrasonic sensors, and servo motors, making it affordable to implement.
6. Reliable Operation: Sensor-based detection provides accurate and reliable operation of the railway gate control system.
7. Reduced Operational Costs: Automation reduces the need for manpower, thereby lowering operational costs for railway authorities [19].
8. Efficient Traffic Management: The system ensures that gates remain closed only when necessary, minimizing traffic congestion on roads.
9. Expandable System: The proposed system can be upgraded with additional technologies such as IoT monitoring, GSM alerts, and real-time train tracking.
10. Practical Application of Embedded Systems: The project demonstrates the practical use of embedded systems and automation technologies in transportation safety systems [20].

## IV. PROBLEM STATEMENT

Railway crossings are among the most accident-prone locations in transportation systems. A large number of accidents occur at these crossings due to the absence of proper monitoring, delayed gate operation, or lack of awareness among road users. Many railway crossings, especially in rural and semi-urban areas, remain unmanned or poorly supervised [21].

Manual gate control systems require continuous human supervision, which increases the possibility of human errors such as negligence, delayed response, or miscommunication. In many cases, gatekeepers may not receive timely information about approaching trains, leading to delays in closing the gates. Such delays can allow vehicles to enter the railway track area when a train is approaching, resulting in serious accidents.

Unmanned railway crossings pose even greater risks because there is no gatekeeper present to regulate traffic. Road users may attempt to cross the railway tracks without knowing whether a train is approaching. This lack of coordination between railway operations and road traffic significantly increases the chances of collisions [22].

Another challenge in railway gate management is the need for efficient and reliable detection systems that can identify approaching trains in real time. Traditional mechanical or manual systems are often insufficient to handle modern railway traffic demands. Therefore, there is a need for an automated railway gate control system that can detect the presence of trains accurately and operate the gates automatically without relying on human intervention. Such a system should be reliable, cost-effective, and capable of improving safety at railway crossings [23].

## V. LITERATURE REVIEW

Automation in railway gate control systems has gained significant attention over the last decade due to increasing railway accidents at unmanned crossings. Researchers have proposed several solutions using sensors, microcontrollers, IoT, computer vision, and wireless communication technologies to improve safety and efficiency at railway crossings.

1. Sheikh Shanawaz Mostafa et al. (2010) proposed a radio-based intelligent railway crossing system designed to reduce collisions at railway level crossings. The system uses wireless communication between trains and a central controller to transmit information about the train's direction and identity. Based on the received signals, the controller automatically decides when to close or open the railway gate. The proposed system eliminates dependency on manual gate operation and reduces the risk of accidents caused by human error [24].

2. Banuchandar et al. (2012) proposed an automated system for unmanned railway crossings using sensors and microcontrollers. The system detects approaching trains using infrared sensors placed along the railway track. Once the train is detected, the system automatically closes the gate and activates warning signals to alert road users. After the train passes the crossing, the system reopens the gate automatically [25].

3. A. K. Dewangan, M. Gupta and P. Patel (2012) developed a microcontroller-based railway gate automation system designed to minimize accidents at level crossings. The system uses sensors to detect train arrival and departure. The microcontroller processes the sensor signals and controls the opening and closing of the gates using motors. The authors emphasized that automated systems provide faster response time compared to manual systems [26].

4. Ahmed Salih Mahdi Al-Zuhairi (2013) proposed a sensor-based automatic railway gate control system using microcontrollers. The system integrates infrared sensors with a microcontroller to detect the presence of trains near railway crossings. When a train approaches, the system activates alarms and automatically closes the gates to prevent vehicles from crossing the track [27].

5. Pwint H. N. Y., Tun Z. M., and Tun H. M. (2014) proposed a microcontroller-based automatic railway gate control system aimed at improving safety in railway crossings. The system detects trains using sensors and automatically controls the operation of gates. The design also includes signal lights and alarm systems to warn vehicles and pedestrians about approaching trains [28].

6. Saifuddin Mahmud, Ishtiaq Reza Emon, and Md. Mohaimin Billah (2015) proposed an automated railway gate controlling system designed to replace manual gate operation. Their system includes modules for train detection, obstacle detection, alarm signaling, and gate control. The train detection module identifies the arrival of trains, while the gate controller automatically closes the gate to prevent road traffic from crossing the track [29].

7. Shrirao S. and Rojatkar D. (2016) presented a review of existing railway gate automation technologies. Their study examined various sensor-based approaches including infrared sensors, RFID systems, and microcontroller-based control mechanisms. The authors concluded that automated systems significantly improve safety at railway crossings compared to manual systems [30].

8. Leena G., Chetan Singh and Nitesh Jha (2017) developed an automated railway system that integrates railway gate automation with track switching and signal control. The system utilizes sensors and microcontrollers to detect train movement and control railway operations. Their research highlighted the importance of intelligent railway infrastructure capable of automatically responding to train movements [31].

9. Mahmud R. and Sarker A. (2018) proposed an RFID-based railway gate automation system to improve the accuracy of train detection. RFID tags installed on trains transmit signals to RFID readers installed near railway crossings. When the system detects the RFID signal, it automatically activates the gate control mechanism [32].

10. Khan M., Singh H., and Rathore A. K. (2019) proposed a railway gate automation system that integrates GSM communication technology with microcontroller-based control. The system sends SMS alerts to railway authorities when trains approach a crossing. Sensors detect train movement and automatically operate the gates [33].

11. Waghware A., Ghate H., Maske G., and Kurzekar P. (2020) proposed an IoT-based railway crossing control system that enables remote monitoring and control of railway gates. The system integrates sensors, microcontrollers, and cloud-based platforms to monitor train movement and gate status [34].

12. P. Ilampiray et al. (2021) proposed an automated railway gate system using Arduino microcontroller and ultrasonic sensors. The sensors detect the arrival and departure of trains, and the microcontroller controls servo motors to operate the gates automatically. The proposed system is designed to reduce accidents at unmanned railway crossings [35].

13. Puja Bhowmik et al. (2022) developed an IoT-based railway crossing automation system that integrates sensors, servo motors, and microcontrollers. The system detects approaching trains and automatically controls the gate operation. Additionally, the system includes obstacle detection to identify vehicles or pedestrians stuck at the crossing [36].

14. A. Ali et al. (2025) proposed a next-generation railway crossing system based on IoT technology and smart sensors. The system uses NodeMCU microcontrollers and vibration sensors to detect trains and control railway gates automatically. Real-time monitoring is achieved through cloud-based communication systems [37].

Hardware Description

1. Arduino Uno Microcontroller

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started [38].

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 programmed as a USB-to-serial converter. The Arduino board serves as the central control unit, processing sensor data and controlling the servo motor for gate operation.

Fig.2. Arduino Uno Microcontroller

Specifications:
Microcontroller: ATmega328
Operating Voltage: 5V
Input Voltage (recommended): 7-12V
Digital I/O Pins: 14 (of which 6 provide PWM output)
Analog Input Pins: 6
DC Current per I/O Pin: 40 mA
Flash Memory: 32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM: 2 KB (ATmega328)
EEPROM: 1 KB (ATmega328)
Clock Speed: 16 MHz

2. Ultrasonic Sensor (HC-SR04)

The HC-SR04 ultrasonic sensor is used to detect the presence of trains. It emits ultrasonic sound waves and measures the time taken for the waves to reflect back after hitting an object. When a train approaches the crossing, the ultrasonic sensor detects the train and sends a signal to the microcontroller indicating its presence [39].

Two sensors are typically used in the system. The first sensor detects the arrival of the train, while the second sensor detects the departure of the train from the crossing area. This arrangement ensures accurate gate control and prevents unnecessary gate operation.


Fig.3. Ultrasonic Sensor HC-SR04

Specifications:
Operating Voltage: 5V DC
Operating Current: 15mA
Effective Angle: <15°
Ranging Distance: 2cm – 400cm
Accuracy: 3mm
Trigger Input Signal: 10µS TTL pulse
Echo Output Signal: TTL pulse proportional to distance range

3. Servo Motor (SG90)
The servo motor is responsible for the physical movement of the railway gate. It converts electrical signals received from the microcontroller into mechanical motion. When the microcontroller detects an approaching train, it sends a signal to the servo motor to rotate and close the gate. After the train passes, the microcontroller instructs the servo motor to rotate in the opposite direction to reopen the gate [40]. Servo motors are preferred in such applications because they provide precise angular control and reliable operation. The SG90 micro servo motor is commonly used for small-scale prototype applications.


Fig.4. Servo Motor SG90

Specifications:
Operating Voltage: 4.8V – 6.0V
Operating Speed: 0.12 sec/60° (4.8V)
Stall Torque: 1.8 kg/cm (4.8V)
Operating Angle: 0° – 180°
Weight: 9g

4. SPDT Switch
The SPDT (Single Pole Double Throw) switch is used as a manual override and system activation control in the Automatic Railway Gate Control System. This switch provides an additional layer of safety by allowing manual operation of the railway gate in case of sensor failure or emergency situations. The switch can also be used to activate or deactivate the automatic mode of the system, giving the operator full control over the gate operation when needed [41].
The SPDT switch has three terminals: one common terminal (pole) and two output terminals (throws). The common terminal is connected to one of the two throws depending on the switch position. This configuration allows the switch to select between two different circuit paths, making it ideal for mode selection (automatic/manual) or for manual gate open/close control.

Fig.5. SPDT Switch

5. Power Supply Unit
The power supply unit provides electrical energy to all components of the system, including the microcontroller, sensors, and motors. A stable power supply is essential for the proper functioning of the system. Typically, a regulated DC power supply is used to ensure that the electronic components receive the correct voltage [42].
The power supply consists of a step-down transformer (230V/12V), a bridge rectifier for AC to DC conversion, a filter capacitor for ripple removal, and a voltage regulator (7805) to maintain a constant 5V output.

Fig.6. Block Diagram of Power Supply

## VI. RESULTS AND DISCUSSION

The Automatic Railway Gate Control System was successfully implemented using an Arduino Uno microcontroller, HC-SR04 ultrasonic sensors, and an SG90 servo motor. The system was tested under various conditions to evaluate its performance in detecting trains and controlling the railway gate automatically.

During testing, the ultrasonic sensors accurately detected the presence of approaching trains within the specified range of 2cm to 400cm. When an object representing a train was placed within the detection range of the first sensor, the sensor sent a signal to the Arduino microcontroller. The microcontroller processed the signal and activated the servo motor, which rotated to close the railway gate within approximately 1-2 seconds [43].

The system provided clear visual feedback through indicator LEDs that showed the status of gate operation. A green LED indicated that the gate was open and no train was approaching, while a red LED illuminated when a train was detected and the gate was closing or closed. This allowed nearby users to understand the current state of the railway crossing at a glance.

Once the train passed the crossing area and was detected by the second ultrasonic sensor, the microcontroller commanded the servo motor to reopen the gate. The indicator LEDs updated accordingly, with the green LED turning back on to signal that road traffic could resume safely [44].

The system demonstrated fast response time and reliable operation. The servo motor provided precise angular control, ensuring that the gate closed completely when a train approached and opened fully after the train passed. The use of two ultrasonic sensors prevented false triggering and ensured that the gate only operated when necessary.

The power supply unit provided stable 5V DC to all components, ensuring uninterrupted operation. The system consumed approximately 200mA of current during normal operation, with the servo motor drawing slightly more current during gate movement.

Overall, the results confirm that the proposed automatic railway gate control system effectively detects trains and operates railway gates without human intervention, thereby improving safety at railway crossings, particularly at unmanned

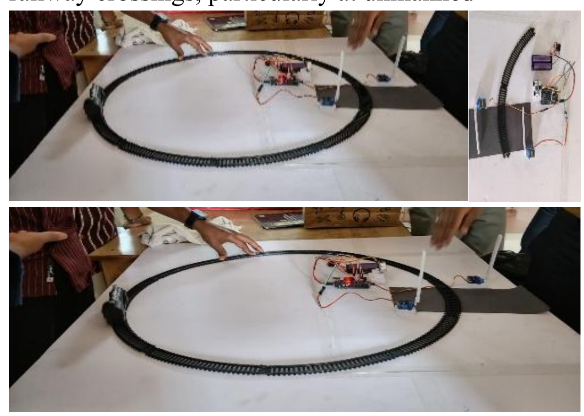

Fig.7. Automatic Railway Gate Control System Prototype

Advantages

1. Reduced Human Intervention: The system operates automatically, eliminating the need for manual gate operation.
2. Improved Safety: Automatic detection ensures timely gate closure, reducing accident risks.
3. Fast Response Time: The system responds quickly to train detection.
4. Suitable for Unmanned Crossings: Ideal for locations without gatekeepers.
5. Cost-Effective: Uses affordable components for implementation.
6. Reliable Operation: Sensor-based detection ensures accuracy.
7. Reduced Operational Costs: Automation minimizes manpower requirements.
8. Efficient Traffic Management: Gates close only when necessary.
9. Real-Time Status Display: LCD shows current system status.
10. Expandable: Can be upgraded with additional features.

Applications

1. Unmanned Railway Crossings: Ideal for rural and remote areas without gatekeepers.
2. Urban Railway Crossings: Improves traffic management in busy urban areas.
3. Smart Transportation Systems: Can be integrated into intelligent transportation infrastructure.
4. Railway Safety Systems: Enhances safety protocols for railway authorities.
5. Educational Demonstrations: Useful for teaching embedded systems and automation concepts.
6. Industrial Automation Training: Provides practical examples of sensor-based automation.
7. Smart City Infrastructure: Can be incorporated into smart city projects.
8. Emergency Response Systems: Enables quick gate operation during emergencies.

## VII. CONCLUSION

The Automatic Railway Gate Control System was successfully designed and implemented using an Arduino microcontroller, ultrasonic sensors, and a servo motor. The system effectively detects approaching trains and automatically controls the opening and closing of railway gates without requiring human intervention. The use of two ultrasonic sensors ensures accurate detection of train arrival and departure, while the servo motor provides precise gate movement [45].

The system addresses the critical issue of accidents at railway crossings, particularly at unmanned locations where manual gate operation is not available. By eliminating human errors and ensuring timely gate operation, the system significantly improves safety for both railway passengers and road users.

The prototype model demonstrates that the system is reliable, cost-effective, and suitable for real-world implementation. The LCD display provides clear status information, and the automatic operation reduces the workload on railway staff. The system's modular design allows for future enhancements such as IoT integration, GSM alerts, and obstacle detection [46].

Overall, this project successfully demonstrates how embedded systems and sensor technologies can be applied to solve real-world transportation safety problems, contributing to the development of smarter and safer railway infrastructure.

Future Enhancements

Although the proposed automatic railway gate control system provides a reliable solution for railway crossing automation, several improvements can be made in the future to enhance its functionality and performance.

Integration with IoT Technology: The system can be integrated with Internet of Things platforms to enable remote monitoring and control of railway gates. Railway authorities can monitor gate operations and receive alerts in real time [47].

GSM or SMS Alert System: A GSM module can be added to send SMS alerts to railway officials or nearby traffic authorities when a train approaches the crossing.

Obstacle Detection System: Additional sensors such as infrared or camera-based systems can be implemented to detect vehicles or pedestrians trapped between the gates, preventing accidents.

GPS-Based Train Tracking: The system can be enhanced using GPS technology to track train locations and predict arrival times more accurately [48].

Solar Power Supply: The system can be powered using solar energy to ensure uninterrupted operation in remote areas.

Wireless Communication Systems: Wireless modules can connect multiple railway crossings for centralized monitoring.

Artificial Intelligence Integration: AI and machine learning techniques can predict train arrival times and optimize gate operation.

Real-Time Monitoring Dashboard: A web-based dashboard can allow authorities to track multiple railway gates from a central location [49].

Automatic Warning Signals: The system can be expanded to include automatic warning lights and alarms to alert road users.

Multiple Gate Control: The system can be designed to control multiple gates at complex crossings with multiple tracks.

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